CFD Simulations of He-Cooled Porous Media

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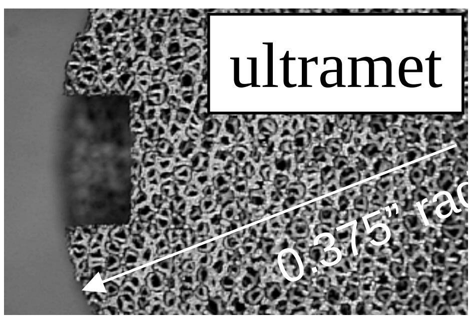
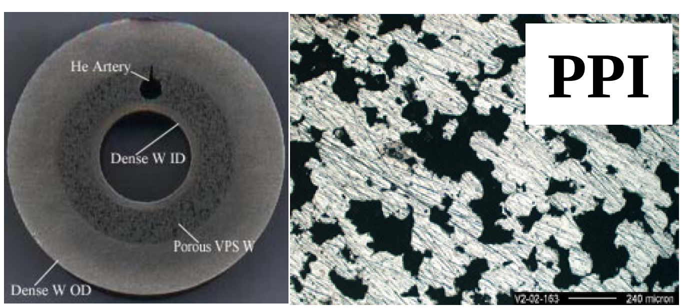
Refractory heat exchangers make sense for next generation devices.

- Helium has advantages over water and liquid metals
- Porous media increases effective heat transfer, h**A**
- Use Brayton cycle for high efficiency, ε=.65,
  high temperature operation.
- Compatible with refractory armor joining, monolithic pfcs
- He may already be used in a solid breeder blanket
- Applications: blanket, divertor, diagnostics, mirrors, shields

Several types of porous media are available.

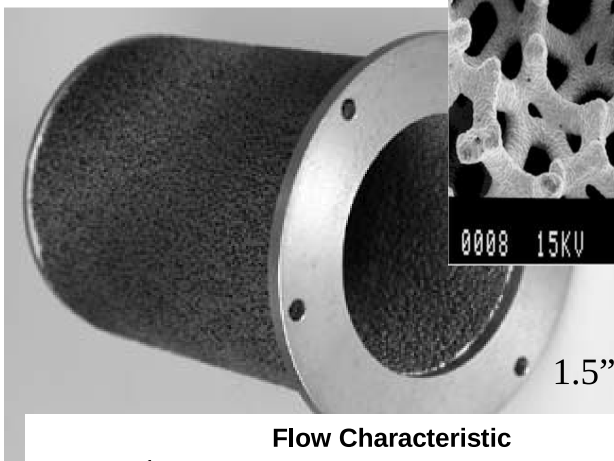
- Brazed spheres or pellets (Thermacore)
- Plasma-sprayed refractory alloys (Plasma Processes)
- CVI refractory foams from RVC precursors (Ultramet)
- Microlaminated sheets - microchannels (Saddleback)

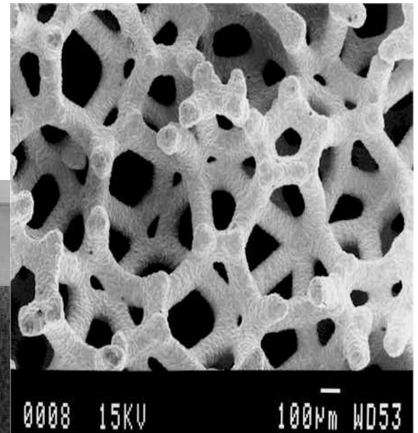




New developments are the product of a 3-year CRADA with Ultramet.

6-mm-thick

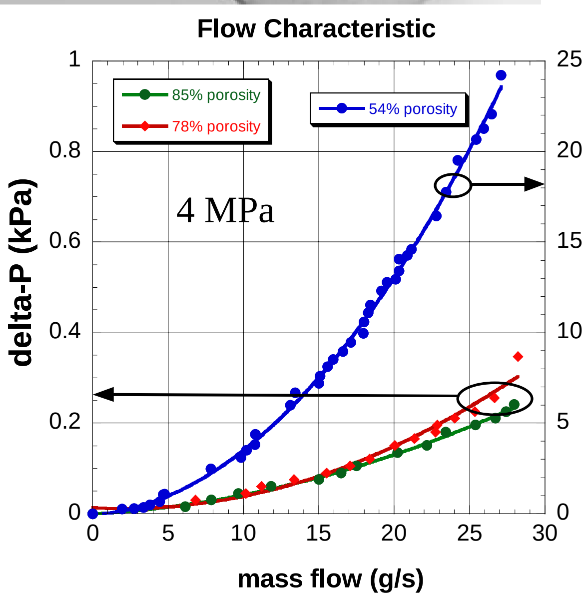


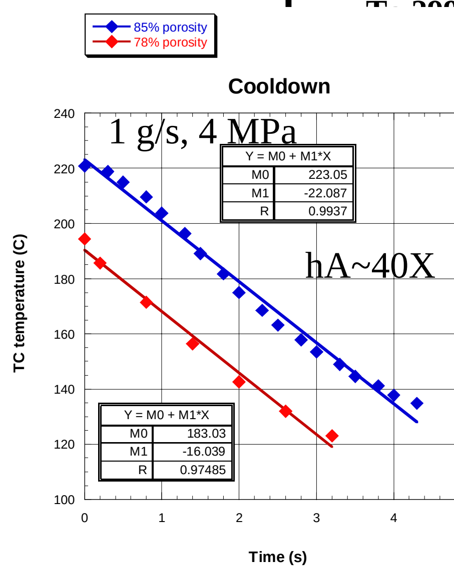


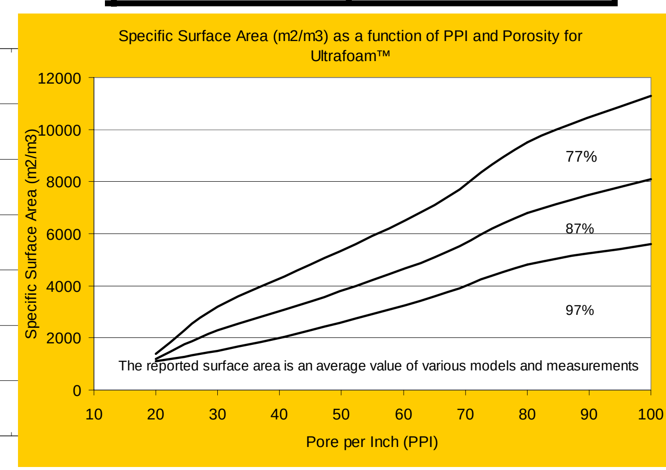
1.5”ID,2.0”OD,2.5” long

Some of the materials deposited by Ultramet

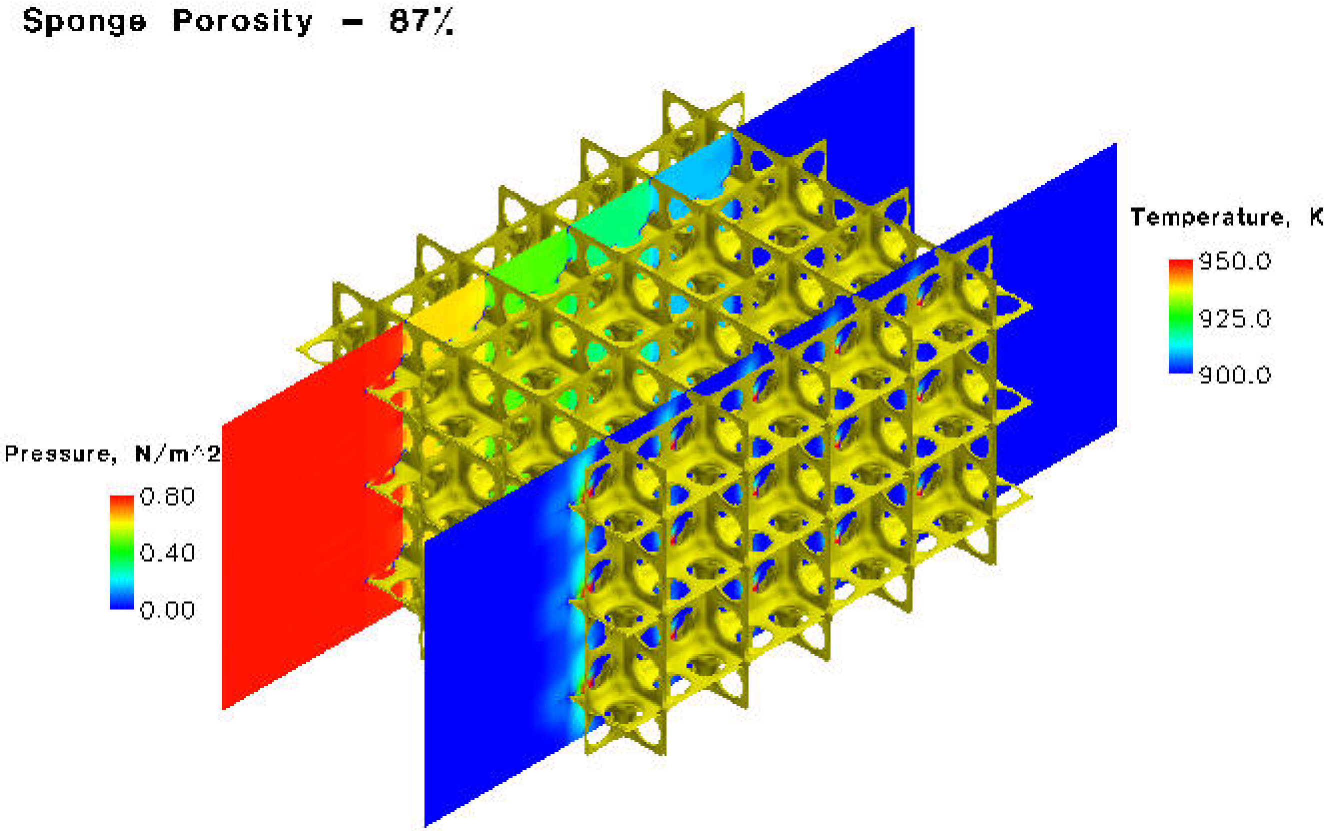
HfC 3890C m. p.	TiN 2930 m. p.	Hf 2227 m. p.
TaC 3880	WB_2 2900	Rh 1966
C 3550 (sub.)	NbN_2 2900	Si_3N_4 1900 (sub.)
ZrC 3540	TiB_2 2900	V 1890
NbC 3500	HfO_2 2897	Ta_2O_5 1872
W 3410	WC 2870	Zr 1852
TaN 3360	VC 2810	TiO_2 1840
HfN 3305	ZrO_2 2715	Pt 1772
Re 3180	SiC 2700 (sub.)	Ti 1660
TiC 3140	Mo 2610	SiO_2 1600
HfB_2 3100	NbN 2573	Fe 1535
TaB_2 3000	Nb 2468	Ni 1455
ZrB_2 3000	Ir 2410	Si 1410
BN 3000 (sub.)	B_4C 2350	Cu 1083
	VN 2320	
	B 2300	







First started with periodic geometry for CFD models generated from single tack model.



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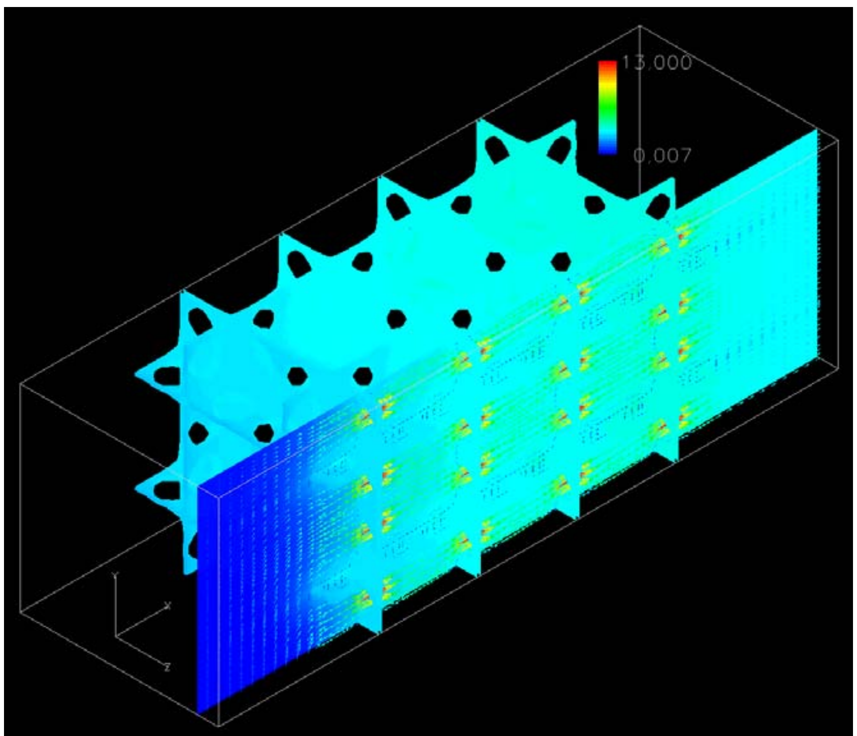
Conjugate heat transfer in ligaments convection to/from fluid

Scale-up to engineering tool:
MP processing on 256-node cluster

LIBERTY

0.1 m/s He, 4 MPa
Q=10 W/cc



<u>Micro-model</u>

Auto generation

Periodic cells

Variable porosity windows

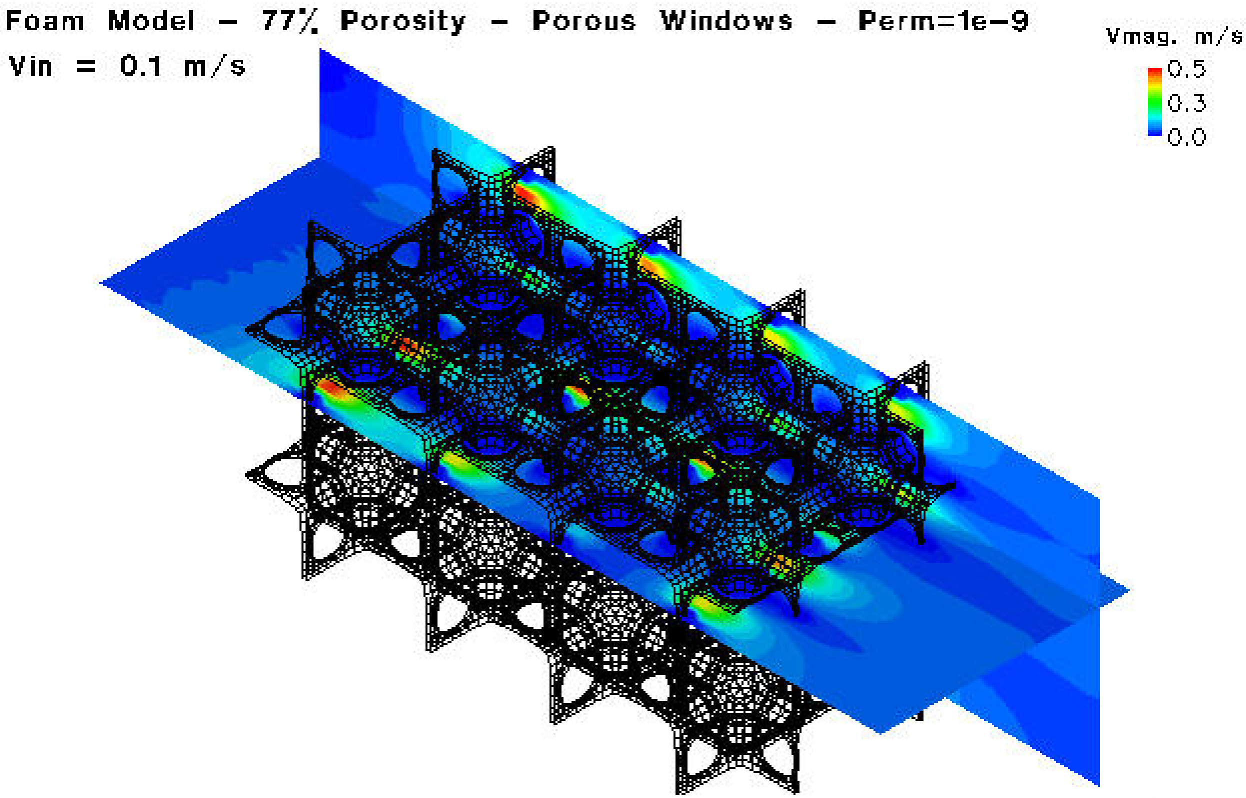
Variable ligament sizes

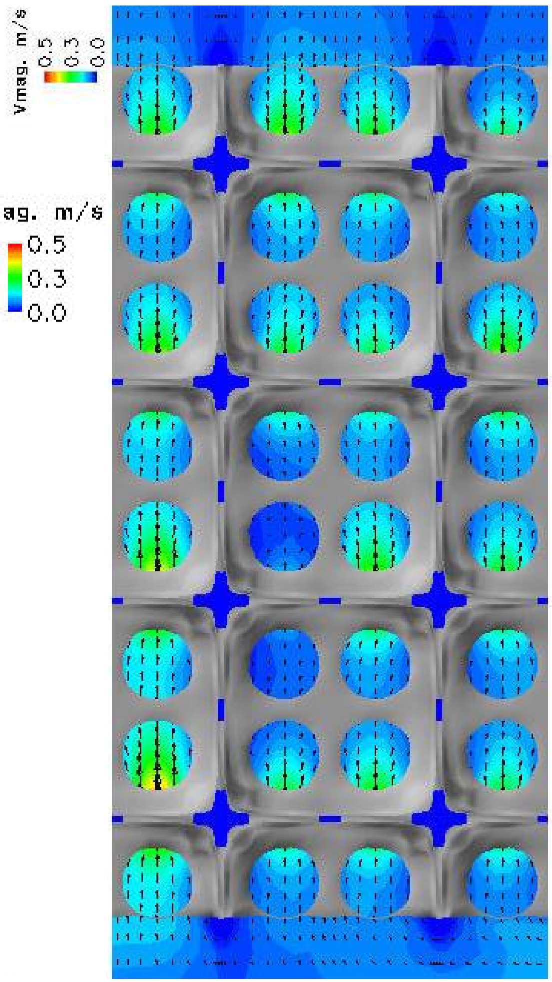
Variable cell sizes

Random cells, MP

Variable porosity windows simulate random window sizes in foam.

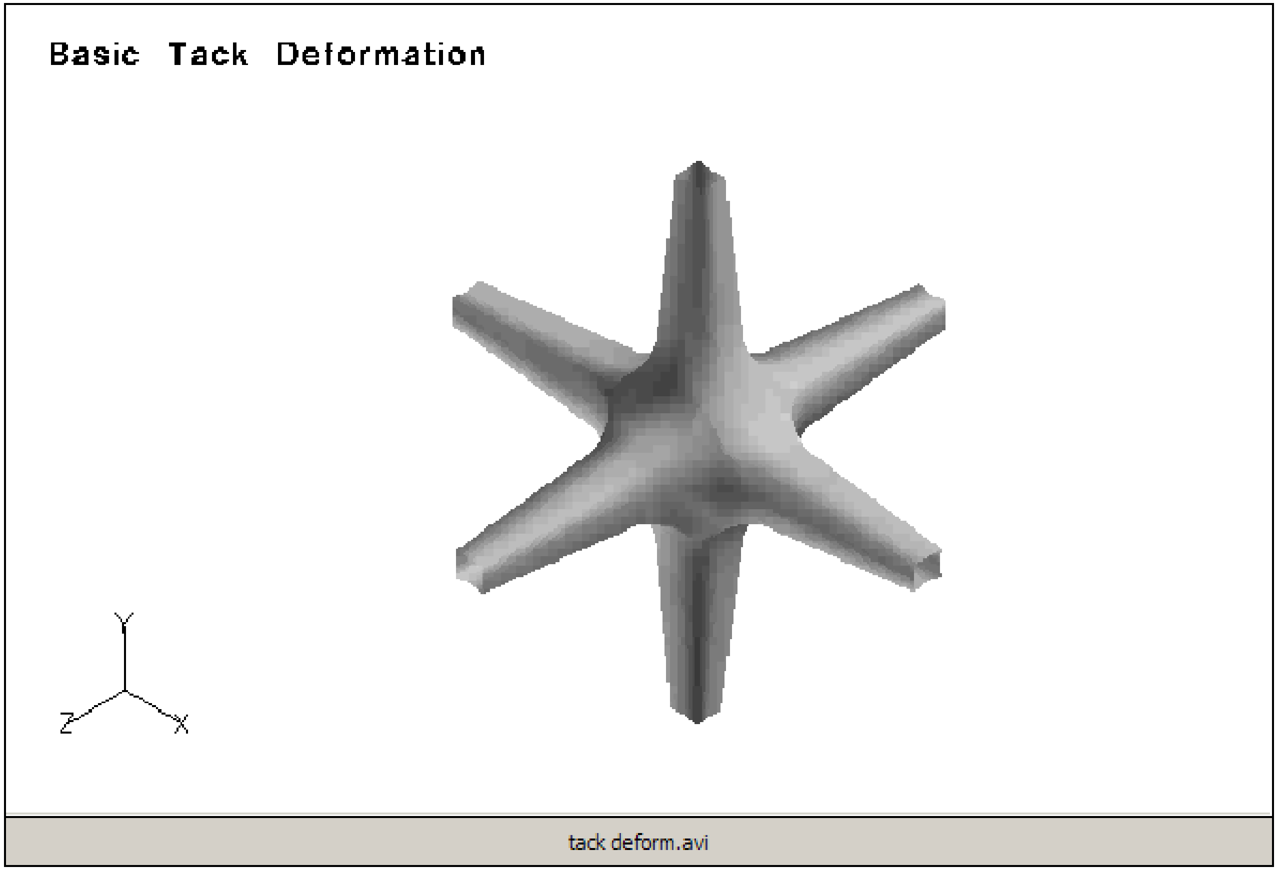
Porous Windows



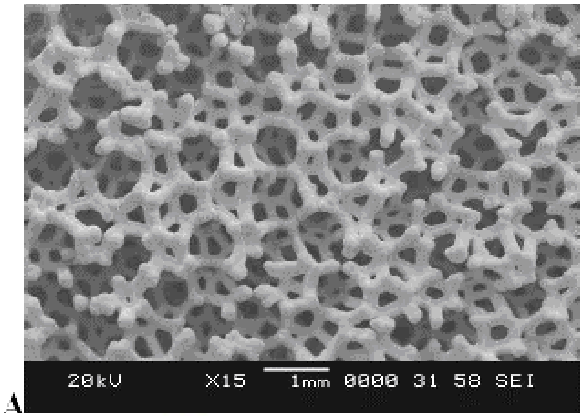


The foam model is based on a “tack” unit cell.

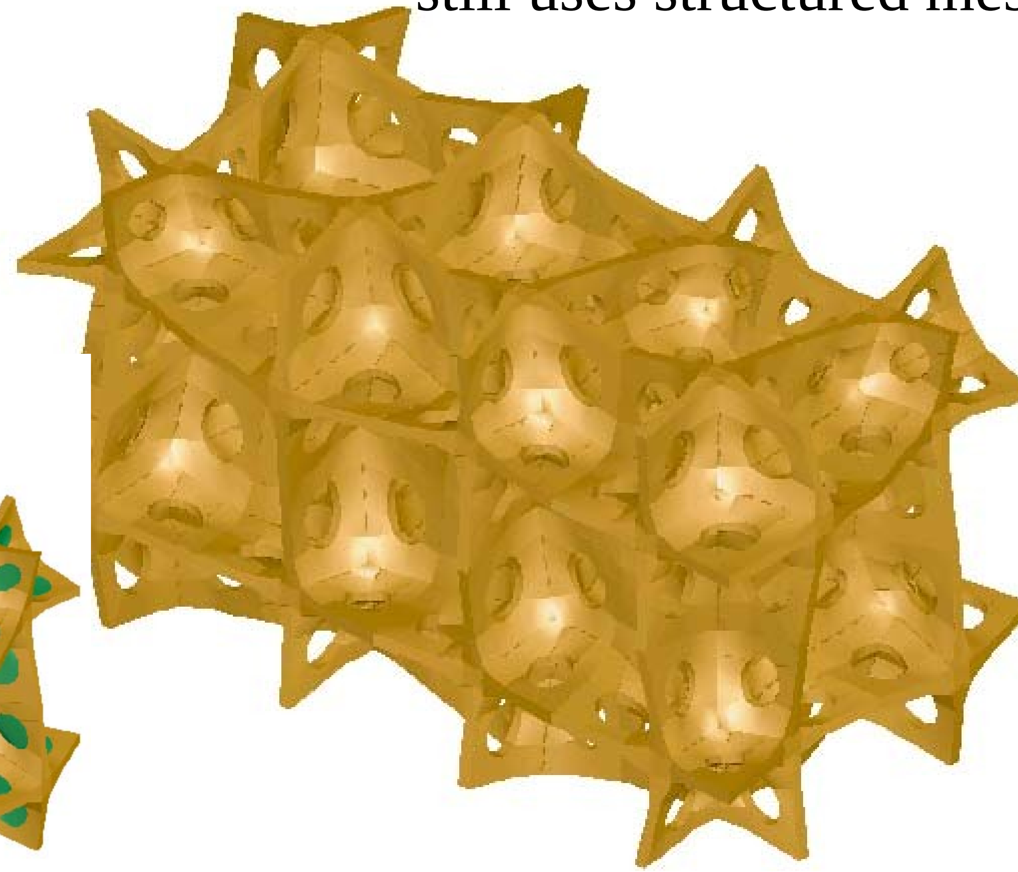
Model Deformation

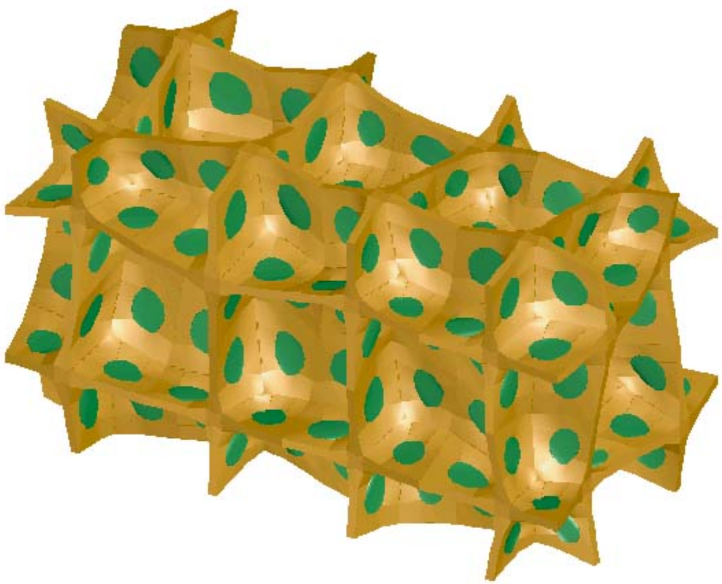


Mesh deformation used to produce aperiodic foam structure for CFD FVM analysis.



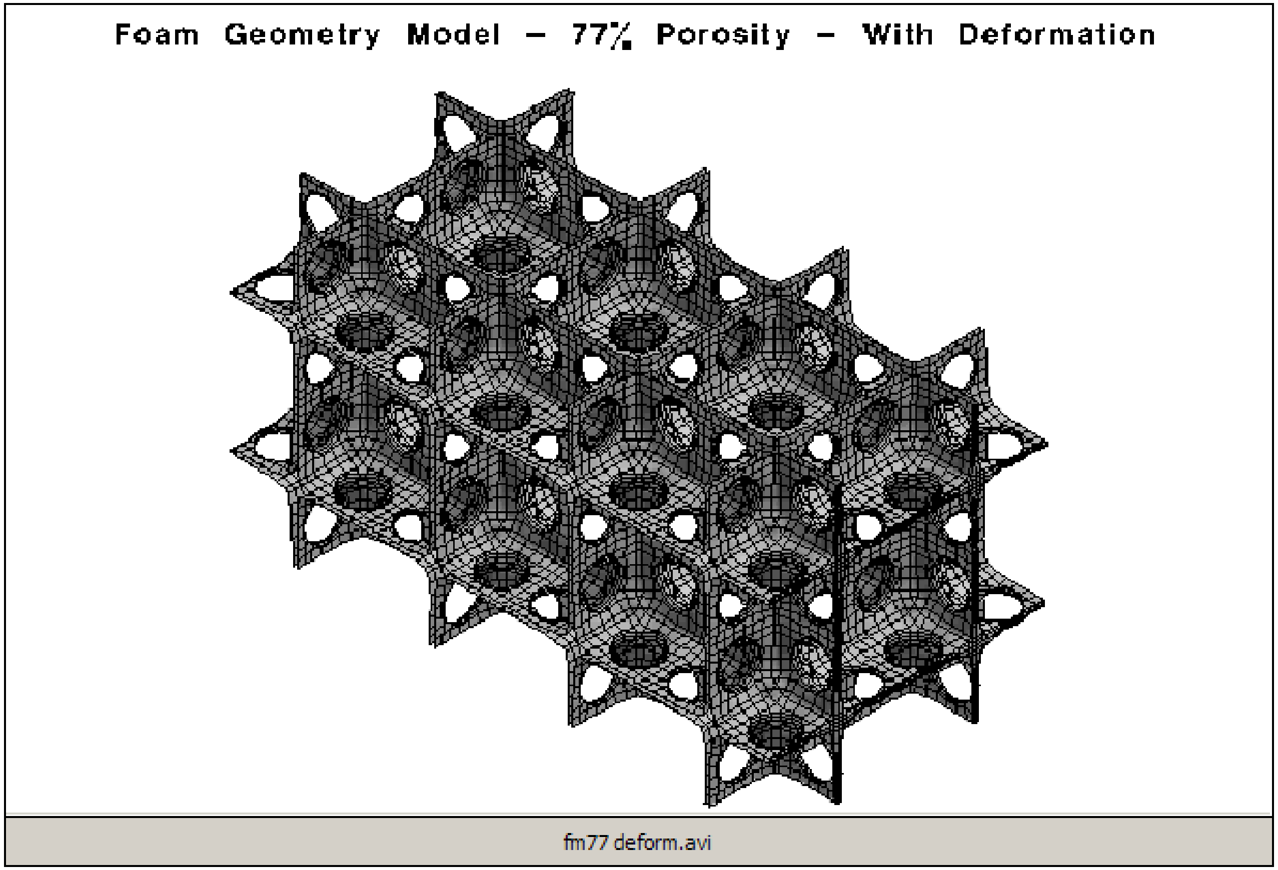
still uses structured mesh!





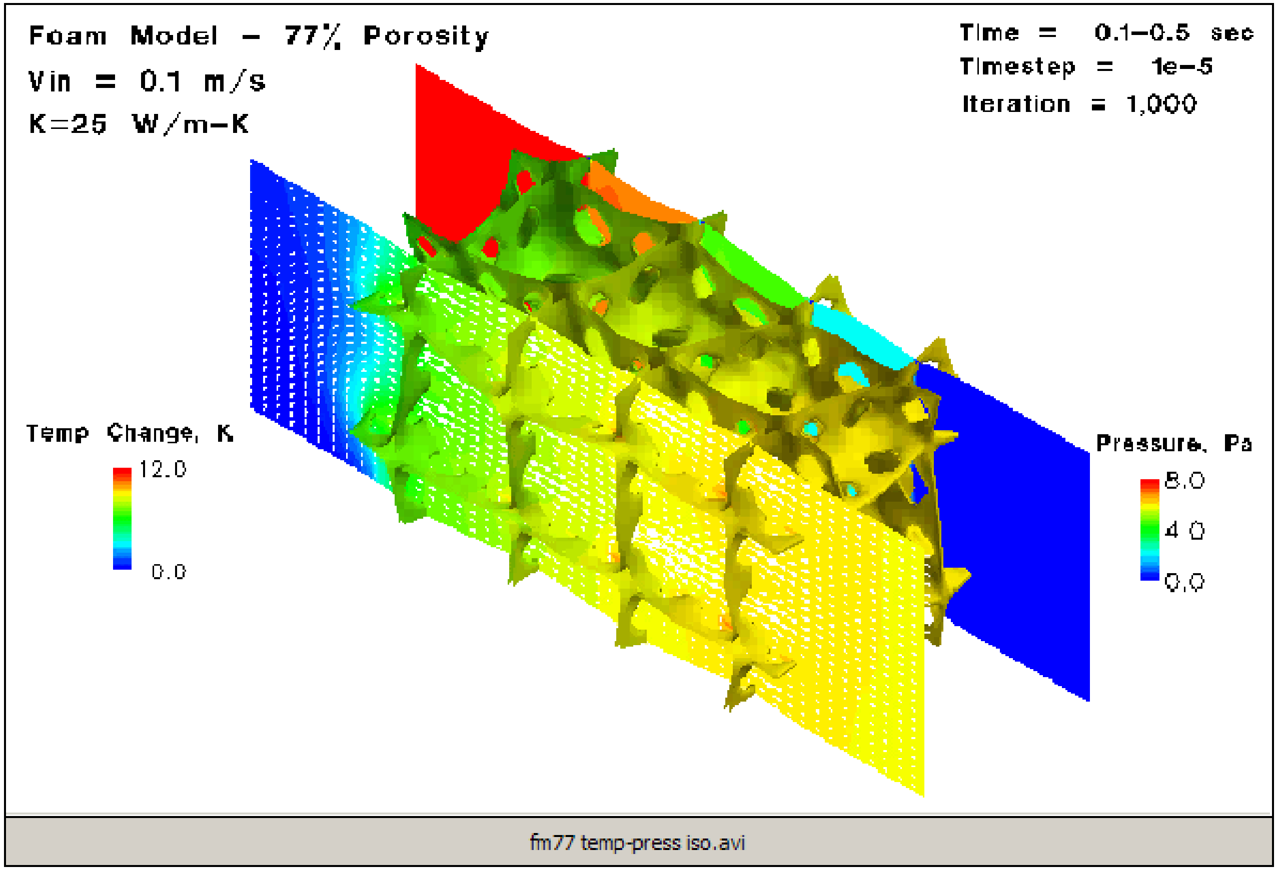
Deform the mesh to obtain realistic geometry.

Model Deformation



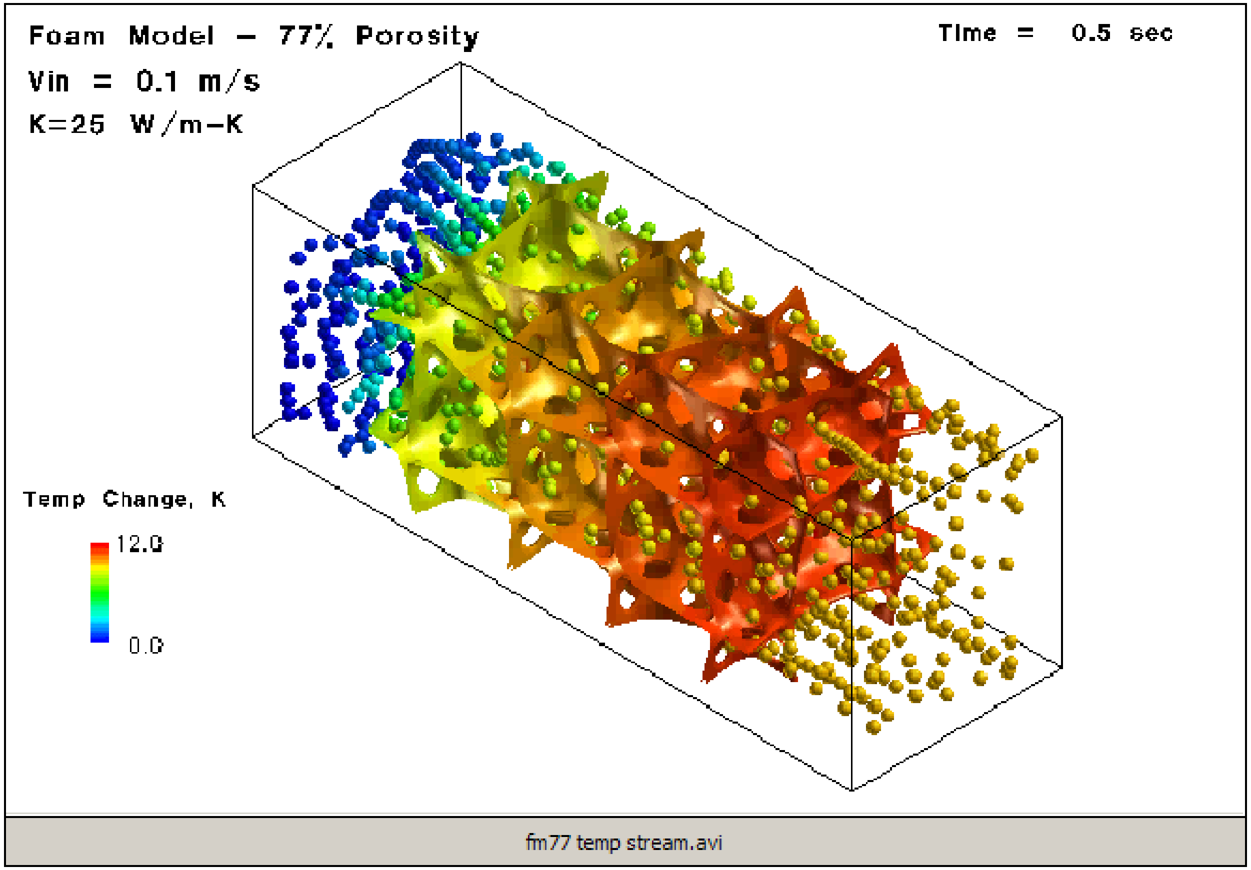
Simulation of helium heating from foam HX

Transient Solution



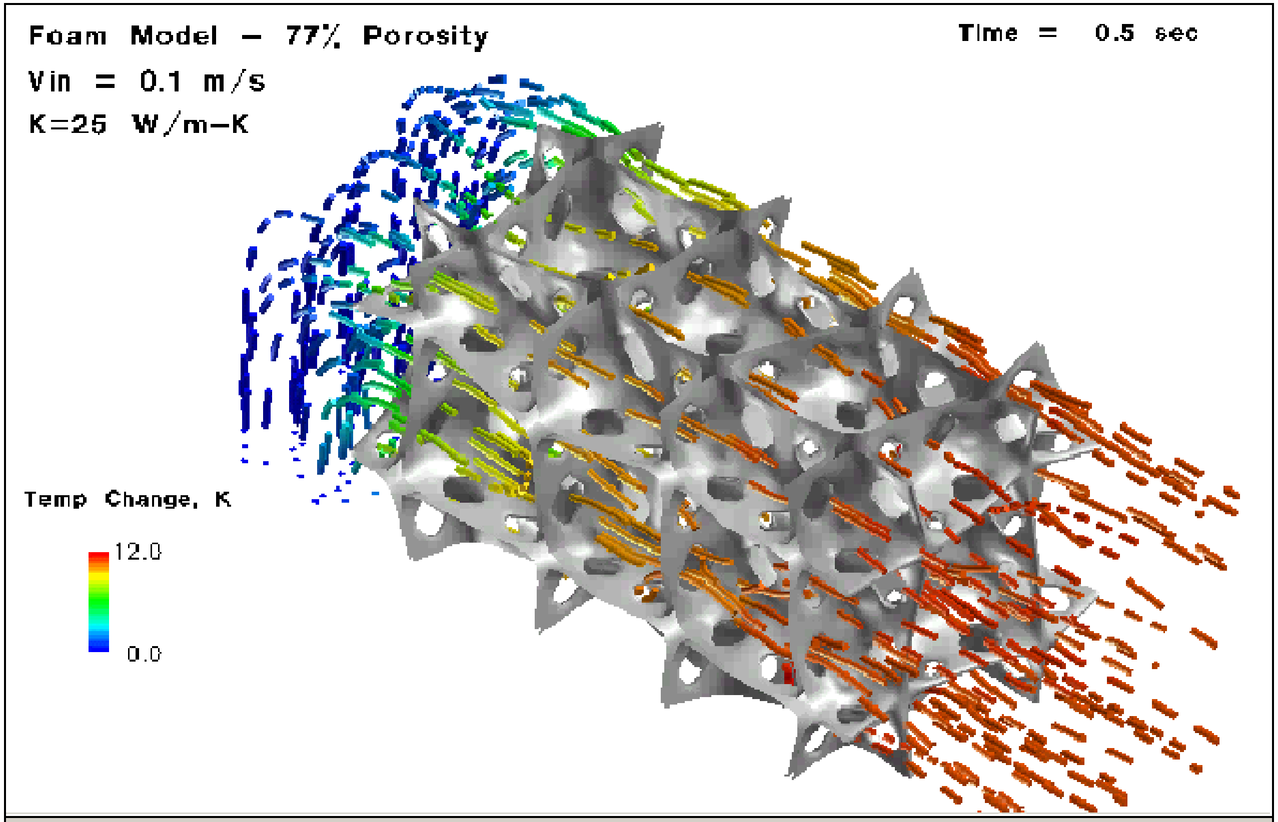
Develop design correlations for heat transfer, pressure drop

Streamlines



Parametric optimization studies are now possible.
(porosity, permeability, ligament size & conductivity, flow parameters)

Streamlines



fm77 temp stream2.avi

Conclusions

- MP version finished by 12/31.
- Model foam annuli in radial flow
- Develop HX and pressure drop correlations for design work
- Benchmark results with heating experiments on refractory foams

Ultramet foams can be engineered for optimal properties for a variety of applications (MFE, IFE, space, commercial)